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REA-1 TRANSPOSITION SYSTEM

Contents

1. GENERAL

1.01 This section is intended to provide REA borrowers, consulting engineers and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. It discusses in particular the application of the REA-1 Transposition System.

1.02 The REA-1 Transposition System provides transposition patterns for up to eight pairs on two Type A or Type B crossarms. The crossarm spacing is 24 inches. This transposition system provides for only four pairs per 10 foot crossarm in order to obtain increased separation between pairs. Voice frequency and carrier frequency circuits may be routed over any pair. The carrier systems may be trunk or subscriber or both. The transposition system provides for the use of point transpositions in windy areas and tandem transpositions in non-windy areas. Since the pole pairs are omitted in all

cases, Type A crossarms should be used for separate or joint pole lines except where point type transposition brackets are used on joint lines. In this case Type B crossarms should be used to provide climbing space.

1.03 General. The R-1 transposition system (REA-TE and CM Section 462) has been widely used in rural open wire construction. It has the advantages of simplicity in engineering and construction, low hardware cost and relative effectiveness against noise in the voice frequency range. However, the R-1 system was designed primarily for use in the voice frequency range and, from the standpoints of crosstalk and noise, the available data indicate that it is not too well suited to multi-system applications in the carrier frequency range. With the R-1 system, the engineering of carrier systems is difficult since only meager information is available on carrier frequency noise and carrier frequency crosstalk between different pairs of wires. The REA-1 transposition system is intended to retain much of the simplicity and economy of the R-1 system but also to provide marked improvement in carrier frequency crosstalk losses and noise with consequent simplification in engineering a number of carrier systems on the same open wire line.

1.031 Special Features of REA-1 System. Unlike the R-1 system, the pole pairs are omitted. This is done to improve the crosstalk coupling per unit length between different pairs and to reduce carrier frequency noise and absorption peaks. In the R-1 system, half the pairs are usually transposed at the odd numbered poles, and the other half are transposed at the even numbered poles. Occasionally, to improve crosstalk, the simple transposition patterns are broken by omitting transpositions at poles numbered 25, 50, 75 etc. The REA-1 system follows the same general plan except that transpositions are occasionally omitted or added at poles 16, 32, 48 etc. Unlike the rules for the R-1 system, the rules for the REA-1 system require control of the differences in the sag of the two wires of a pair and the differences in transposition pole spacing. As a result of the required transposition pole spacing control, every pole may not be a transposition pole. The transposition poles should have the transposition pole numbers marked on them as an aid in avoiding transposition errors.

1.032 Crosstalk Performance of REA-1 System. The expected crosstalk performance over a range of carrier frequencies is outlined on Table 1 and discussed in Paragraph 4, ENGINEERING CONSIDERATIONS.

1.033 Absorption Losses. At the higher carrier frequencies a considerable part of the energy, which it is desired to transmit over a pair, may be absorbed in adjacent wires. Such extra transmission losses are discussed under ENGINEERING CONSIDERATIONS.

2. PHYSICAL DESCRIPTION

2.01 Figures 1, 2, 3 and 4 and Table 2 indicate the physical layout of the REA-1 Transposition System. Two hundred and fifty-six transposition poles are shown on Figure 1. When there are two or more pairs of wires, at least one pair is transposed at each transposition pole. There may be one or more additional (set-in) poles between any two transposition poles depending on whether or not it is practicable to string the wires in straight lines between transposition poles. The discussion in Paragraph 4 -- ENGINEERING CONSIDERATIONS assumes that an average transposition pole spacing of 300 feet is representative. The effect of other average transposition pole spacings on the usable frequency range is also discussed there. Permissible deviations in transposition pole spacing below or above the average are discussed in Paragraph 4.06.

2.02 Diagram of the REA-1 Transposition System

2.021 The layout of the REA-1 Transposition System is shown in Figure 1. Each vertical line on the diagram indicates a transposition pole. Circuits 1, 3, 6 and 8 are usually transposed at the even numbered transposition poles. Circuits 2, 4, 5 and 7 are usually transposed at the odd numbered transposition poles. It may be noted that there is considerable similarily to the R-1 system except for poles which are multiples of 25. This was explained in paragraph 1.031. It should be also noted that the transpositions at transposition pole 256 on Figure 1 are different from those at this pole as shown on Figures marked 2 and 2A and attached to tentative memoranda on the REA-1 Transposition System.

2.022 The notation ○ in Figure 1 (for instance at pole 32, pair 1-2) signifies that a transposition is omitted from the simple patterns discussed above. In cases 1 and 3 (point brackets, A or B cross-arms) no special arrangements are required at such points; the wires are tied to insulators such as Type 17, in the normal manner, to preserve 12 or 10 inch spacing.

2.023 In case 2, (tandem brackets Type A crossarms) a double groove insulator, such as Type 56, should be placed at points designated ○ . At such points the two wires are to be brought to different grooves on opposite sides of the insulator to achieve a "pinch-in" spacing of about 2.5". The wires then must separate, without being transposed, and return to the normal non-transposed spacing of 14" at adjacent transposition poles. For example, see Figure 1, case 2 circuit No. 1 Transposition pole 32. In case 2, specially spaced deadend clevises are required at the zero pole as shown in Figure 8 DETC, in order to preserve normal wire spacing.

2.024 The designation ⊗ refers to a point type transposition in cases 1 to 3 which is a departure from the simple patterns discussed in 2.021. In cases 1 and 3, the designation refers to a point type transposition because all the transpositions are of the point type. In case 2, the designation refers to a point type transposition rather than to the tandem type transposition which is usually used in case 2. In this case, whenever a pair must have a transposition designated ⊗ there are tandem transpositions at both adjacent poles (if each pole is a transposition pole). Tandem transpositions at adjacent poles should not be used because the average wire spacing in the
pan would be only about 2.25". For
eferring to Figure 1 and Table 2, it
hat, for case 2, pair 3-4 is trans-
63, 64 and 65. Therefore, a point
must be used at pole 64.

nay be one or more non-
between two transposition
poles. In such instances, special procedures are required for case 2. These procedures are discussed under Engineering Considerations. (See Paragraphs 4.0631 to 4.0633).

2.03 The REA-1 pattern is to be repeated if the line is longer than 256 spans. The transposition pole numbers 0 to 257 shown on Figure 1 are theoretical and may not correspond to the normal exchange pole numbering. As noted in Figure 1, the transpositions on transposition poles 257 to 512 are like those at transposition poles 1 to 256. For example transposition pole 375 is transposed like pole (375 minus 256) or pole 119. However, Figure 1 is not to be considered as a "transposition section" nor is pole 256 an "S" pole.

2.04 Any pair may leave the main lead at any transposition pole or dead end. However, better crosstalk performance is to be expected if a particular pair leaves the lead at even numbered pole: still better performance is to be expected if the circuit leaves at pole 64 or 128 or 256 or 512 rather than a few poles more or less than these numbers. At a junction between the main lead and a branch lead, the transposition pole numbering on the main lead should be continued on both leads.

2.05 The pole numbers shown are arbitrarily started with zero, which is a dead-end pole, either at the central office or at the entrance cable junction pole. The pole top assembly for the dead end (at pole zero) should be selected from Figure 8 so as to preserve the wire spacing as indicated in Figures 2, 3, 4, 5 and 6.

2.06 The crosstalk and noise performance of a pole line employing the REA-1 system was computed for a maximum length of 512 spans. It is thought that such a length is ample for most applications. A discussion of longer lengths is given under Engineering Considerations, paragraph 4. The absorption peak performance of a pole line employing the REA-1 system was computed for a maximum length of 1024 spans.

2.07 The pole top assembly at the last dead-end pole should be selected so as to preserve the wire spacing (see paragraph 2.023). No transpositions should be installed at the last pole. In case 2, specially spaced dead-end clevises should be used to preserve the normal wire spacings shown on Figure 3. However, with clevises the pinch-in spacing may be 3" rather than 2.5". If the last dead-end pole is an even-numbered transposition pole, the spacings of Figure 8, DET C are correct for the top crossarms. For the second arm the crossarm is rotated 180 degrees. Specially spaced dead-end clevises should also be used when one or more pairs leave the line at an intermediate

pole, when any pair dead ends or when dead ends are required to turn corners.

2.08 When dead ends are required to turn corners, the dead e crossarms should be cross-connected by using single insu lated wires which follow the most direct route. If the dead end crossarms are at a transposition pole, the proper transpositions should be made by transposing the jumper wires.

3. COORDINATION CONSIDERATIONS

3.01 Coordination is discussed herein with reference to controlling crosstalk between pairs transposed to the REA-1 system. Other coordination considerations such as interference from or into power line carrier or radio facilities in the area might further limit the number of channels of any carrier system which may be employed.

3.02 One terminal of each carrier system on the pole line is to be placed at the same point (maximum of eight carrier systems at one location). This will usually be at the central office, although it may sometimes prove economical to place them at the cable-open wire junction pole. The other terminals of the several systems on the same pole line may be placed at different locations within the limitations specified below. (Paragraph 3.04)

3.03 Frequency Coordination

3.031 No two carrier systems may transmit the same channel bands (or parts of the same channel bands) in opposite directions over different pairs of wires. Such an arrangement usually results in intolerable near-end crosstalk between the input of one carrier system and the output of another carrier system. Therefore, the "E-W" and "W-E" recommendations of the carrier system manufacturer should be adhered to.

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e channel bands in the
rent pairs of wires may
crosstalk between them.
of crosstalk between
s over a range of carrier
in Table 1, pairs on
ole for channels using
pairs on the second

3.033 To permit the use of the higher carrier frequencies over pairs of the REA-1 system, manufacturers may resort to the following means of reducing crosstalk between carrier systems transmitting the same channel bands in the same direction over different pairs of wires: (1) use of normal and staggered frequency allocations (2) use of frequency or phase modulation (3) use of compandors.

3.04 Level Coordination. Proper application of the REA-1 Transposition System depends upon level coordination among the various carrier systems on the pole line. Level differences of the same frequencies in the same direction of transmission should be engineered not to exceed 3 db. This may be accomplished through the use of attenuator pads or other means of output level control as discussed in REA-TE and CM Section 901.

3.05 Taps on Pole Line. When a pair or drop carrying only a voice channel is tapped onto a pair with one or more carrier channels on a pole line transposed to the REA-1 system, a voice pass filter must be placed in the tapping pair or drop if one or more carrier channels are routed over the tapped pair. The purpose of a filter is to prevent carrier frequency currents from entering the tap. If a carrier channel is routed over the tap, it is necessary to place filters in both the tapping pair and the tapped pair. These filters prevent other carrier channel currents from entering the tap. They also prevent the carrier channel routed over the tap from transmitting in both directions on the main line which would increase the probability of crosstalk and cause carrier frequency transmission loss. Carrier manufacturers' recommendations should be obtained as to the proper type of filters.

3.06 Due to crosstalk and attenuation characteristics of cable, it may be desirable to overbuild cable with one crossarm of the REA-1 system. The possibility of interaction crosstalk via the cable strand or sheath makes it necessary that vertical distance from the wires to the cable be kept at a minimum of two feet.

3.07 Other Transposition Systems. In general it is recommended that the REA-1 transposition system be not employed on the same pole line with any other transposition system.

4. ENGINEERING CONSIDERATIONS

4.01 Type of Conductor. The type of conductor to be used for carrier frequencies will normally be determined by "wet" weather attenuation considerations (refer to REA-TE and CM Section 406) at the highest frequency of the pair having the longest electrical length. Once the carrier frequency conductor is so chosen, it will be necessary that all other pairs on the same pole line to be used for carrier frequencies be of the same conductor, even though their individual transmission requirements would permit a less expensive conductor. Pairs to be used only at voice frequencies may use any conductors that meet transmission and signaling requirements.

4.02 Spacing Between Crossarms. The REA-1 system was designed for a minimum crossarm spacing of 24 inches. Shorter spacing should be avoided.

4.03 Transposition Pole Spacings. Paragraph 2.01 mentions a representative transposition pole spacing of 300 feet. In some cases it may be economical to use some other average transposition pole spacing, say, 400 feet. In such a case, the carrier frequencies listed on Table 1 must be reduced by a factor of 300/400. Likewise, if an average transposition pole spacing of 250 feet is used, the carrier frequencies of Table 1 must be increased by a factor of 300/250. Choice of an average transposition pole spacing of other than 300 feet requires consideration of (a) choice of conductors of suitable strength and (b) determining whether decreasing or increasing the number of channels per pair (as determined from Table 1) results in reducing the cost per channel mile.

4.04 Joint Use with Electric Distribution Facilities. If the line is in a windy area and point transpositions are used to minimize hits, it is necessary to use type B crossarms in the case of joint use with electric distribution facilities. The type B crossarms provide climbing space between circuits numbered 2 and 3 or 6 and 7 (see Table 2 and Figures 1 and 4). It is important that in all the spans of a pole line the crosstalk coupling (per unit length) between two pairs be as nearly equal as possible. Therefore, with the exception of a few type B arms which may be employed at power contact poles, if any continuous joint use with electric distribution facilities is planned, the entire line, including those portions not in joint use, must be designed with type B crossarms (see Table 2 and Figure 4).

4.05 Mixture of Point Type and Tandem Type Transpositions. As discussed in paragraph 2.024, in case 2 for which tandem transpositions are largely used, there is occasional use of point type transpositions. With this exception, a pole line should not have a mixture of the two kinds of transpositions. In other words, a line should not be transposed partly in accordance with cases 1 and 3 of Table 2 and partly in accordance with case 2. Such procedure would cause too much variation in the crosstalk coupling per span between two pairs.

4.06 Control of Irregularities of Pole and Wire Spacing.

4.061 Differences in Wire Sag. For satisfactory crosstalk performance to be realized, the difference in the sags of the two wires of a pair should not be excessive. It is recommended that in initial construction the deviation in sag of any wire from the sag recommended by the wire manufacturer be limited to two inches to allow for additional deviations later on.

4.062 Difference in Transposition Pole Spacing.

Let U be the deviation, in feet, of a transposition interval from the average length of all the intervals. (For the REA-1 system, the average interval may be about the same as the average span length). Let L be the length of the line in feet. The rule is:

$$\sum U^2 \leq 6L$$

That is, the sum of all the valu
not exceed 6L. It is desirable
as small as practical
talk and noise. T
necessary when exi

4.0621 Many trans
the O-1 sy
sections a
poles. Th
lengths an
position i
deviations
position s
the U^2 val
The grand
pared with

some constant (such as 3, 1, 1/3 etc.). This
cedure is practicable because each transpositi
section involves enough transpositions to appr
mately balance out crosstalk. Therefore, it is
not essential to make two successive sections
nearly the same length in order that crosstalk
the first section may be balanced out by crosst
in the second section.

-.0622 The above procedure is not directly applicable w
the REA-1 transposition system because this syst
does not have definite transposition sections in
which the crosstalk is approximately balanced out
However, for the purpose of calculating sums of U
values while staking, a length of 64 transpositio
poles may be regarded as a transposition section
desired. The length of any such 64 pole "Section"
should not vary from the average length of all 64
pole sections by more than 10 percent.

-.0623 An example of calculating the sum of the U^2 deviations for only eight transposition pole intervals and an average interval of 300 feet is as follows:

Exchange Pole Number	Transposition Pole Number	Backspan-feet	U	U^2
1	1			
2	2	300	0	0
3	3	340	40	1600
4	4	260	40	1600
5	5	325	25	625
6	*	275	25	625
7	6	175		
8	7	200	75	5625
9	8	250	50	2500
		275	25	625
		L = 2400		13200 = 5.5L

* This is not a transposition pole. Pole top assembly units will not show transposition brackets.

e sum of U^2 values meets the
the sum shall not exceed 6L.
let the average transposition
In eight intervals 6L
or 14,400 feet. If seven
hort of the average and one
112 feet longer than the
of the U^2 values would be

$7 \times 16^2 + 112^2$ or 14,336 which is practically 6L. The maximum permissible deviation of any interval of the eight from the average interval would be 112 feet. The maximum permissible deviation increases with the number of spans. By keeping all the deviations but one as small as possible the maximum positive deviation (increase over average interval) may be calculated from the following formula:

$$M = \sqrt{6\ (N-1)\ A}$$

M is the maximum deviation in feet, N = number of intervals and A is the average interval length in feet. For N = 64 and A = 300, M is about 337 feet. In order to permit this value of M and not change A, all other (N-1) intervals must be shorter than A by $\frac{M}{N-1}$ or about 5 feet. More precisely, all other intervals must be shorter than A and the sum of the squares of their deviations must be $\frac{M^2}{(N-1)}$.

4.0624 In some sections of a line it may be desired to have shorter pole spacing in order to support a cable unde[illegible] open wire. Transpos[illegible] deviations may [illegible] making the a[illegible] that in the other pole [illegible] offers no di[illegible] Table 2. I[illegible] be necessar[illegible] as discusse[illegible] 4.0632 and i[illegible]

4.0625 If a single [illegible] is necessar[illegible] pole spacin[illegible] noise reaso[illegible] reasons.

4.0626 As discussed in paragraph 4.0623 occasi long spans may be used by keeping most the transposition interval deviations a small as possible. Such long spans may needed for crossing streams or gullies c to avoid setting a pole at some difficul location. In some cases, it may be nece sary to increase the size of conductor f strength reasons and to increase the distance between the two wires of a pair. For crosstalk and noise reasons the distances between all the wires on the line should be increased in the same proportio In case 2 of Table 2 and Figure 3, the relative spacings at the span center shoul be preserved in the long span.

4.063 Treatment of Occasional Non-Transposition Poles. For new lines, the above rule for transposition pole spacing deviations will probably be met with no difficulty. The rule is made as lenient as crosstalk standards would permit. Existing lines, however, may have quite irregular pole spacing and it may be found that the limit for the squared sum of the pole spacing deviations is missed by a wide margin if every pole is made a transposition pole. It may be possible, however, to meet the rule of deviations by choosing the transposition poles so that some of the transposition intervals contain one or more non-transposition poles. For example, if the average pole spacing is about 300 feet and two adjacent spans of 100 and 250 feet are encountered, the two spans can be used for a transposition interval and the squared sum of the deviations (from the new average) can be improved. For case 2 which involves tandem transpositions special procedures are required when there are occasional non-transposition poles in a transposition interval. This is discussed below.

4.0631 In considering occasional non-transposition poles and tandem type transpositions, the principle to remember is that in a transposition interval the wires of a pair should taper from 14" to 2.5". Therefore, if a transposition interval contains a non-transposition pole, reboring of the crossarms at the non-transposition pole is necessary in the manner shown in Figure 5.

4.0632 At the top of this figure is shown two transposition intervals between transposition poles 2 and 4 for two representative pairs 1-2 and 3-4. The solid lines show the configuration of the wires if there were no non-transposition pole. Half of a tandem transposition is shown in pair 1-2 at pole 2. The dotted lines show a possible method of taking care of the non-transposition pole. This method is satisfactory from the crosstalk standpoint. However, since pair 3-4 arrives at transposition pole 1 with 14 inch spacing an expensive point type transposition would be required. The practical solution is to rebore the crossarms at the non-transposition pole in such a way that the solid line configuration is approximately maintained at the non-transposition pole. For the two pairs on Figure 5, new pin holes (and number 17 insulators) would be required for wires 2 and 3.

4.0633 At the lower part of Figure 5 is shown a transposition interval (pole 2 to pole 3) with two non-transposition poles. In this case, the wires can be arranged, as indicated by the solid lines. In general, if there are an even number of non-transposition poles in a transposition interval, no reboring is required. If there are an odd number of non-transposition poles in a transposition interval, the crossarms on the non-transposition pole nearest the end of the interval must be rebored. The points where the new pin holes are to be bored may be determined by inspection of Figures 3 and 5. Sufficient wire spacing accuracy may be obtained by assuming there is one non-transposition pole at which the reboring is done midway between two adjacent poles. It is desirable to realize this condition if at all possible. The new pin hole spacings for the rebored crossarms (either first or second) is shown at the bottom of Figure 5.

4.07 Lines with Short Average Pole Spacing. (Every other p normally a transposition pole.) Cases may arise when or existing lines have relatively short average pole s ing and it would be economical to arrange to have two spans in almost all the transposition intervals. This requires no special procedure in cases 1 and 3, Table 2 but causes complications in case 2. The procedure discussed, in paragraphs 4.0631 and 4.0632, for handling one non-transposition pole in a transposition interval would require reboring all the crossarms at the non-transposition poles. This may be avoided by changing the wire configuration from that shown in Figures 3 and 5. The changed configuration causes more crosstalk than the original configuration but the crosstalk increase is expected to be tolerable. The changed configuration is indicated on Figure 6. This configuration is suitable for one or any odd number of non-transposition poles in a transposition interval. With this configuration transpositions marked ⊗ on Figure 1 may be of the tandem type.

4.071 On lines with short pole spacing, it may occasionally be necessary to specify two (or any even number of) non-transposition poles in a transposition interval. To maintain the desired wire configuration it is necessary to rebore the crossarms at the first (or last) non-transposition pole in the manner indicated at the bottom of Figure 5.

4.08 Intermediate Cables. The use of intermediate cables in a line transposed to the REA-1 transposition system is undesirable when carrier frequency systems are routed over the pairs. The objections are (a) the transmission loss at carrier frequencies may be considerably increased, (b) if more than one or t

carrier systems are routed
be serious crosstalk between
reflection reducing
open wire junctions
the near-end cross-
ted crosstalk appears
rd at receiving carrier
ld be avoided as far
e cable is planned
r two carrier systems
engineer.

4.09 Tree Wire. It sometimes happens that proper tree trimming is impracticable. In view of the objection to intermediate cables discussed in paragraph 4.08, single insulated conductors (called tree wire) should ordinarily be used in such situations.

4.10 Measured Crosstalk Losses. The upper sketch of Figure 9 indicates two like pairs of wires a and b extending from A to B. The measured near-end crosstalk loss at end A is indicated by the crosstalk path X_N. This is the insertion loss between the A end of pair a and the A end of pair b. The measured far-end crosstalk loss at end B is indicated by the crosstalk path X_F. This is a transmission loss measured by comparing the power delivered at end B of pair a with the power delivered at end B of pair b. There is also a near-end crosstalk loss at end B which is measured by sending on pair a and receiving on pair b. Likewise, there is a far-end crosstalk loss at end A which is measured by sending on pair a at end B and comparing the two received power values at end A.

4.11 Aimed-at Crosstalk Losses. The aimed-at crosstalk losses are 50 db or more for the far-end loss and 40 db or more for the near-end loss.

4.12 Estimated Crosstalk Losses. The estimated crosstalk losses for the various pair combinations, for various frequency ranges and for lengths up to 512 transposition intervals averaging 300 feet are given on Table 1. The tabular values were obtained partly by calculation and partly by a study of the results of a field trial on 128 transposition intervals averaging 300 feet. In this trial there were four pairs on the top crossarm and the two end pairs (11/12 and 19/20) on the second arm. All six pairs had tandem-type transpositions. While the crosstalk loss values depend somewhat on the number of transposition intervals, it is felt that Table 1 is suitable for engineering carrier systems. As noted in paragraph 4.03, if the average transposition interval is not 300 feet but L feet, the kilocycles on Table 1 should be multiplied by 300/L.

4.13 Interpretation of Table 1. On this table, far-end crosstalk losses less than the objective of 50 db (or more) are underlined. To use two carrier systems in a frequency range where the far-end loss fails to meet the objective (by an important amount), it is necessary to use carrier systems having a crosstalk advantage to make up for the deficiency in crosstalk loss. (See paragraph 3.033.)

Near-end crosstalk losses less than the objective of 40 (or more) are also usually underlined. However, if the far-end loss is less than 50 db and the near-end loss is not less than the far-end loss by 10 db, the near-end l is not underlined. It was reasoned that a crosstalk ad- vantage would be necessary to overcome the deficiency in the far-end loss and that this advantage would also take care of the deficiency in the near-end loss. It may be seen that, for all practicable purposes, combinations of pairs on the top crossarm meet the crosstalk objectives up to 200 kc. Other pair combinations meet the objective up to 100 kc.

4.14 Longer Line Lengths. Table 1 assumes a maximum line length of about 29 miles. In some cases, a longer length may be desired, say 60 miles. There is no objection to extending a single pair for longer lengths. However, if a line with two or more pairs used for carrier frequencies is extended considerably beyond 512 transposition inter- vals, the far-end crosstalk loss may be seriously reduced (3 to 6 db for 1024 intervals). For the longer lines, it is important to adopt a more strict control on the devia- tions in transposition pole spacing. (See paragraph 4.062.) The sum of all the values of U^2 should not exceed 3L rather than 6L. For 1024 transposition intervals, this should result in about the same crosstalk losses as those on Table 1 except as discussed below. For circuit com- binations, 3/4 - 11/12, 3/4 - 17/18, 9/10 - 13/14 and 11/12 - 17/18 the underlined far-end crosstalk losses of Table 1 should be decreased by 6db when considering 1024 transposition intervals rather than 512 intervals.

4.15 ENGINEERING CARRIER SYSTEMS - EFFECT OF CROSSTALK LOSSES

4.151 Far-end Crosstalk Loss. The lower sketch of Figure 9 indicates two pairs with similar amplitude modulated carrier systems without repeaters or com-

iency f_1 is transmitted

ncy f_2 is transmitted B-A.

ined up for zero net loss.

nd of circuit a. Near-

hs at frequency f_1

As a result of X_{F1}

osstalk path X_{FV} be-

nd the B end of cir-

t full volume at the

lume down by the

crosstalk loss X_{FV} at the B end of circuit b. The crosstalk losses X_{FV} and X_{F1} are equal and should not be less than 50 db.

4.152 Near-end Crosstalk Loss. If f_2 were the same carrier frequency as f_1, the talker could talk through the carrier terminal at A_a, through the near-end crosstalk path X_{N1}, through the carrier terminal at A_b and be heard at the A end of circuit b. In other words, there is a voice frequency near-end crosstalk path X_{NV} between the A end of circuit a and the A end of circuit b. There are transmission gains in both transmitting and receiving carrier terminals in order to offset the carrier line loss L. As a result the talker's volume is reduced by the crosstalk loss X_{N1} but increased by a gain equal to L. The crosstalk volume at the A end of circuit b would usually be intolerably loud if f_2 were equal to f_1. Since f_2 is not equal to f_1, there can be an electrical filter in the receiving carrier terminal at A_b which receives f_2 but offers a considerable loss to f_1. As noted on Figure 9, $X_{NV} = X_{N1} - L + L_{f_1f_2}$ where $L_{f_1f_2}$ is the loss of the filter at frequency f_1. X_{NV} should not be less than 50 db.

4.153 Reflected Near-end Crosstalk Loss. Even though X_{NV} can be made a large loss by efficient filtering, it is important to limit X_{N1} because of reflected near-end crosstalk. A crosstalk current is transmitted through X_{N1}. If the impedance encountered by this current in entering the receiving carrier terminal at A_b is not equal to the impedance of the carrier line, a portion of the crosstalk current is reflected and transmitted to B_b where the crosstalk can be heard. A similar reflection effect can occur at the receiving carrier terminal at B_a. Also, reflections can occur at any point in either carrier line where there is an impedance irregularity such as that caused by a length of cable. Since it would be too costly to make X_{N1} as large a loss as X_{F1}, it was decided to aim at a value of X_{N1} which is not more than 10 db less than X_{F1}. This means that if more than about 32% of the near-end crosstalk current is reflected, the reflected near-end current becomes larger than the far-end crosstalk current. Reflection reducing devices at the junctions of open wire and cable will usually be necessary.

4.16 ABSORPTION LOSSES

4.161 General. An insertion loss versus frequency run on any transposed pair shows that when a certain frequency is reached, the insertion loss starts to peak up due to absorption of energy in other wires on the pole line. As the frequency is increased the extra insertion loss due to absorption reaches a maximum and then the loss decreases to the normal value.

4.162 Critical Frequency Range. Theory and a field trial of the REA-1 system (22 mile line, tandem transpositions) indicate that, for 300 foot average transposition pole intervals, serious absorption peaks start at about 350 kc and extend to about 450 kc. In the 22 mile trial, extra loss of as much as 50 db was measured in this frequency range. For pair 7/8, which is transposed at every other transposition pole there was one large peak in the critical frequency range. The maximum value occurred at about 404 kc. The other pairs, which had more complicated transposition patterns, had two or more peaks and valleys in the critical frequency range. For average transposition intervals other than 300 feet, the critical frequencies should be adjusted in inverse proportion.

4.163 Absorption Effects below Critical Frequency Range. Below 350 kc and above 200 kc, the trial of a 22 mile tandem transposed 4 to 8 pair line showed a gradual and irregular transmission loss increase over the calculated per mile values published in REA-TE & CM-406. In the trial the conductors were 104 copperweld 40% conductivity. These increases in loss are not fully understood but, presumably, are due to a number of small absorption losses. In the trial, the wires of the new REA-1 line were quite close to wires of an old line which had to be kept working during the trial. Much work was done in moving the old wires and in most cases the new and old wires were two feet or more apart. It is recommended that, for the present, the published calculated attenuation per unit length be increased as follows:

kc	% Increase	kc	% Increase
200	0	300	30
250	20	350	50

In view of the complication of the old line in the 22 mile trial, another trial may show smaller percentage increases.

4.164 Calculated Absorption Peaks below Critical Frequency Range. Pairs with very simple transposition patterns (such as 7/8) do not, in theory, have absorption peaks below the critical range. For other pairs, relatively small peaks below the critical range are calculated. These are appreciable in long lengths such as 512 to 1024 300 foot transposition intervals. However, it is thought that the attenuation correction discussed above will take care of these minor absorption effects.

TABLE I

Crosstalk Performance of REA-1 Transposition System. Estimated Minimum Near-End and Far-End Crosstalk Losses in db for Lengths Up to 512 Transposition Intervals Averaging 300 Feet (29.1 Miles)

air inations	Kilocycles 0 to 100 NE	FE	100 to 150 NE	FE	150 to 200 NE	FE	200 to 250 NE	FE	250 to 300 NE	FE	300 to 350 NE	FE
- 3/4	46	60	42	60	38	50	36	50	34	41	32	28
- 7/8	46	60	46	60	46	53	46	50	46	42	38	31
- 9/10	60	60	60	60	60	50	55	45	50	40	35	30
- 7/8	48	60	44	50	42	45	38	40	36	35	30	30
- 9/10	46	60	46	55	46	55	46	50	46	44	40	30
3 - 9/10	46	60	42	60	39	55	36	50	34	45	32	34
2 - 11/12	39	60	30	52	30	52	25	34	25	34	21	10
13/14	39	60	39	50	39	46	39	36	39	32	30	17
17/18	60	60	57	60	54	55	51	50	48	45	40	30
19/20	52	60	52	55	52	50	50	46	48	41	40	28
4 - 11/12	38	60	38	55	38	50	38	45	38	37	30	13
13/14	39	60	31	52	30	50	26	40	25	36	22	21
17/18	37	60	37	60	37	58	37	38	37	33	30	11
19/20	60	60	57	60	55	55	52	50	48	45	48	23
/8 - 11/12	60	60	57	60	55	55	52	50	50	45	35	23
13/14	37	60	37	53	37	50	37	40	37			
17/18	39	60	31	56	30	54	26	37				
19/20	38	60	38	60	38	55						

TABLE 2

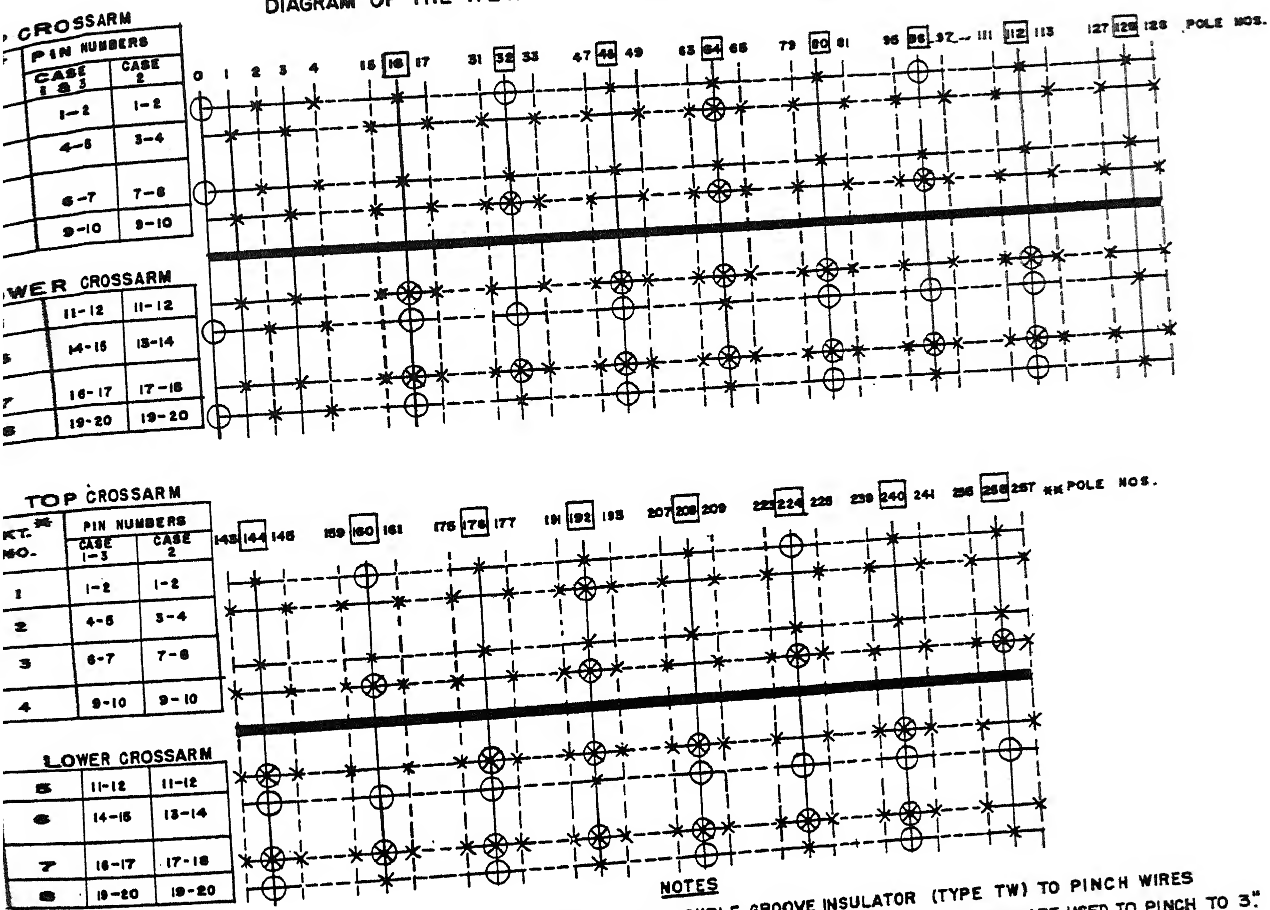
Application of Crossarms, Transposition Brackets, Double Groove Insulators and Dead-end Clevises to REA-1 Transposition System

Case No. (Refer to Fig. 1)	Windy Area	Joint Use with Electric Distribution Facilities	Crossarm Type	Transposition Bracket	Pinch-in Wire Spacing (2.5" or 3") where Designated "O" *	Wire Spacing at Transposition Points	Wire Spacing Non-transposition and Non Pinch-in Points
1	Yes	No	A	Point	No	12"	12"
2	No	No (or Yes)	A	Tandem, except point where designated ⊗	Yes	⊗ = 12", otherwise 2.5"	14"
3	Yes	Yes	B	Point	No	10"	10"

* At dead-end poles wires are pinched-in to 3" spacing using clevises ... pinched-in to 2.5" using double groove insul...

FIGURE 1

DIAGRAM OF THE R E A – 1 TRANSPOSITION SYSTEM



NOTES

○ INDICATES TRANPOSITION OMITTED. USE DOUBLE GROOVE INSULATOR (TYPE TW) TO PINCH WIRES TO 2.5" SPACING IN CASE 2, EXCEPT FOR DEAD END POLES WHERE CLEVISES ARE USED TO PINCH TO 3".

⊗ INDICATES POINT TYPE TRANSPOSITION IN CASES 1,2 AND 3.

X INDICATES POINT TYPE BRACKETS FOR CASES I AND 3, TANDEM BRACKETS FOR CASE 2.

* ARBITRARILY ASSIGNED FOR IDENTIFICATION WITH TABLE 2.

** TRANSPOSE FROM POLE 257 TO 512 LIKE 1 TO 256 ETC.

AT TRANSPOSITION POLES WITH BOXED NUMBERS (16, 32 ETC.) SPECIAL TRANSPOSITION PATTERNS ARE USED.

FOR LAST POLE CASES 1 AND 3– DO NOT TRANSPOSE

FOR LAST POLE CASE 2–SUBSTITUTE ○ FOR X AND OMIT ⊗

IT SHOULD BE ALSO NOTED THAT THE TRANSPOSITIONS AT TRANSPOSITION POLE 256 ON FIGURE I ARE DIFFERENT FROM THOSE AT THIS POLE AS SHOWN ON FIGURES MARKED 2 AND 2A ATTACHED TO TENTATIVE MEMORANDUM ON THE REA TRANSPOSITION SYSTEM.

FIGURE 2

I-WIRE SPACINGS (POINT TYPE BRACKETS TYPE 10A CROSSARMS)

FOR DETAIL OF DEAD-ENDING REFER TO UNIT PBS 11 (FIGURE 7)

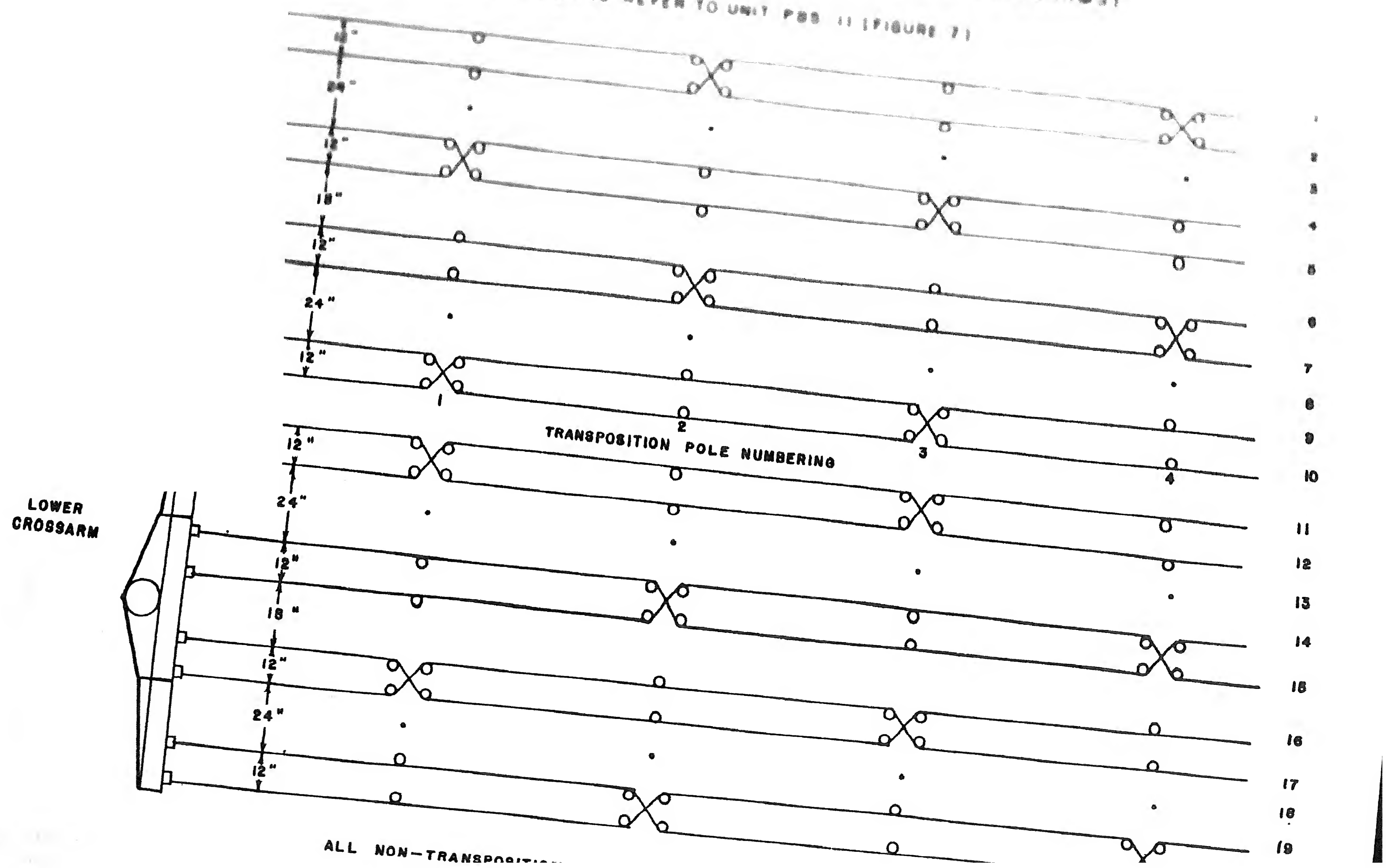
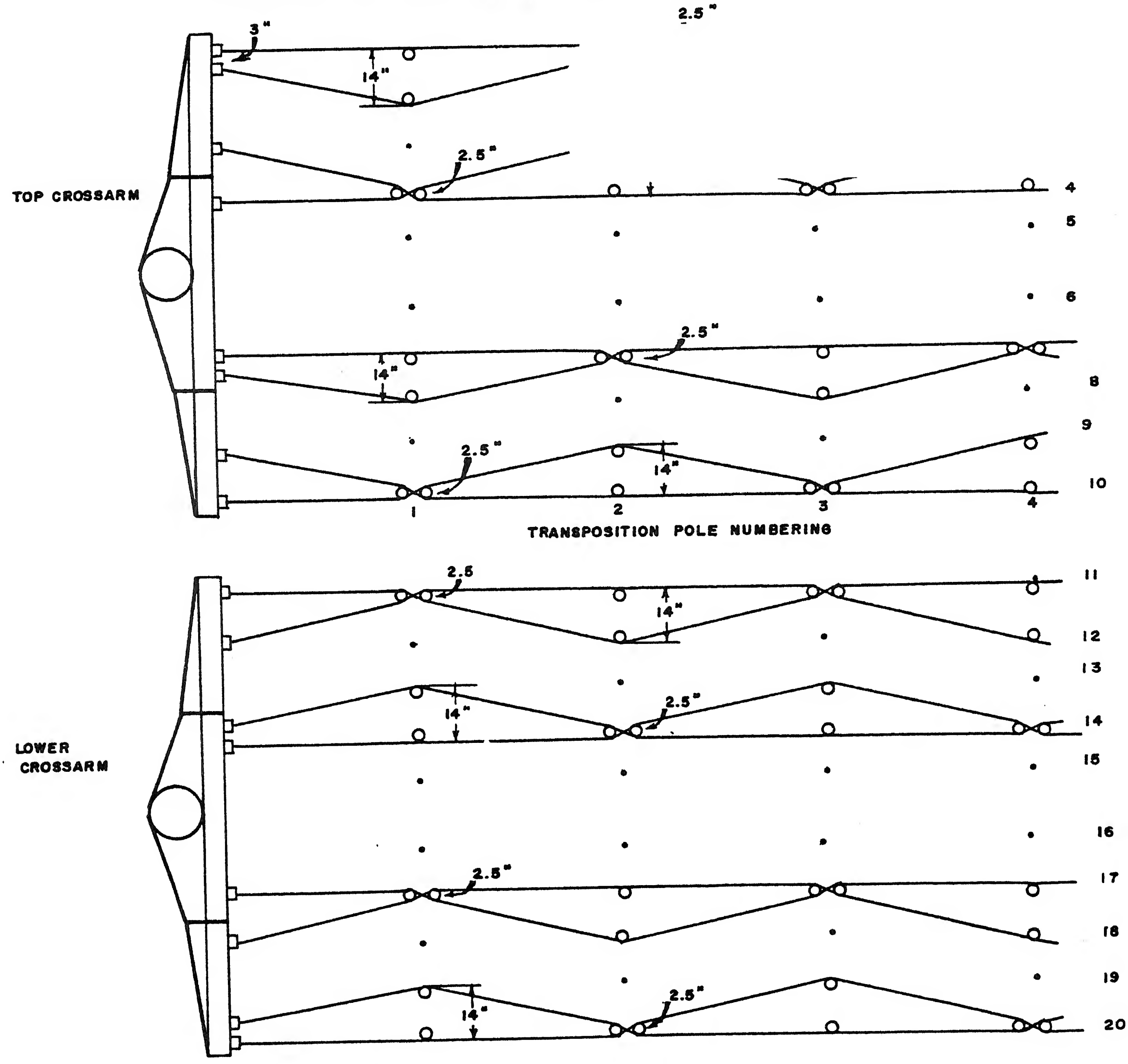


FIGURE 3

CASE 2-WIRE SPACINGS. (TANDEM TYPE BRACKETS- TYPE 10A CROSSARMS)

FOR DETAIL OF DEAD-ENDING REFER TO UNIT PB5-13 (FIGURES 7 AND 8)

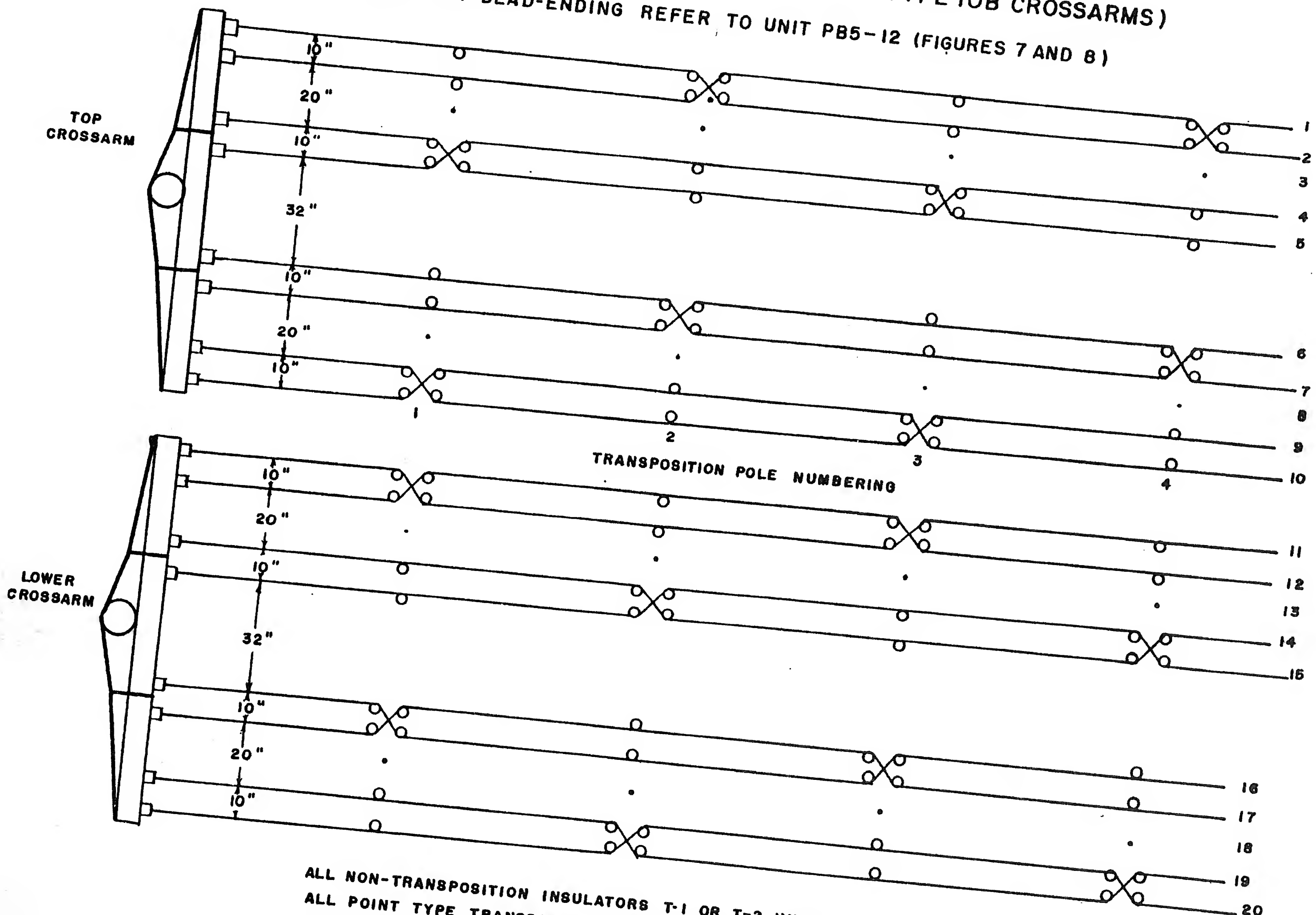


ALL NON-TRANSPOSITION INSULATORS T-1 OR T-2 UNITS.
ALL TANDEM TYPE TRANSPOSITION BRACKETS T-6 OR T-7.
DISTANCE BETWEEN CROSSARMS 24".

FIGURE 4

CASE 3-WIRE SPACINGS (POINT TYPE BRACKETS - TYPE 10B CROSSARMS)

FOR DETAIL OF DEAD-ENDING REFER TO UNIT PB5-12 (FIGURES 7 AND 8)



ALL NON-TRANSPOSITION INSULATORS T-1 OR T-2 UNITS.
ALL POINT TYPE TRANSPOSITION BRACKETS T-14 OR T-19 UNITS.
DISTANCE BETWEEN CROSSARMS 24"

FIGURE 5

CASE 2 - TREATMENT OF OCCASIONAL NON-TRANSPOSITION POLES

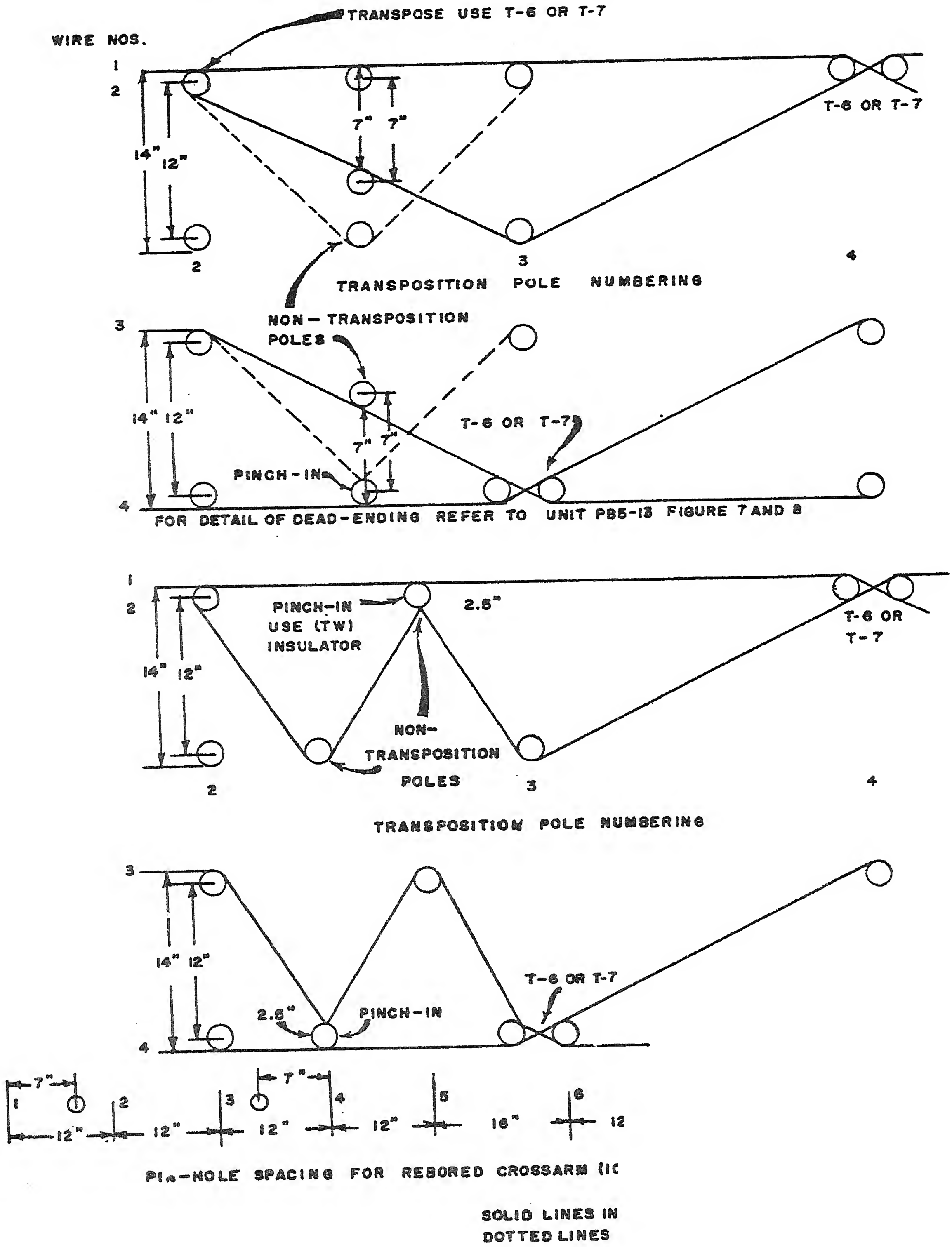
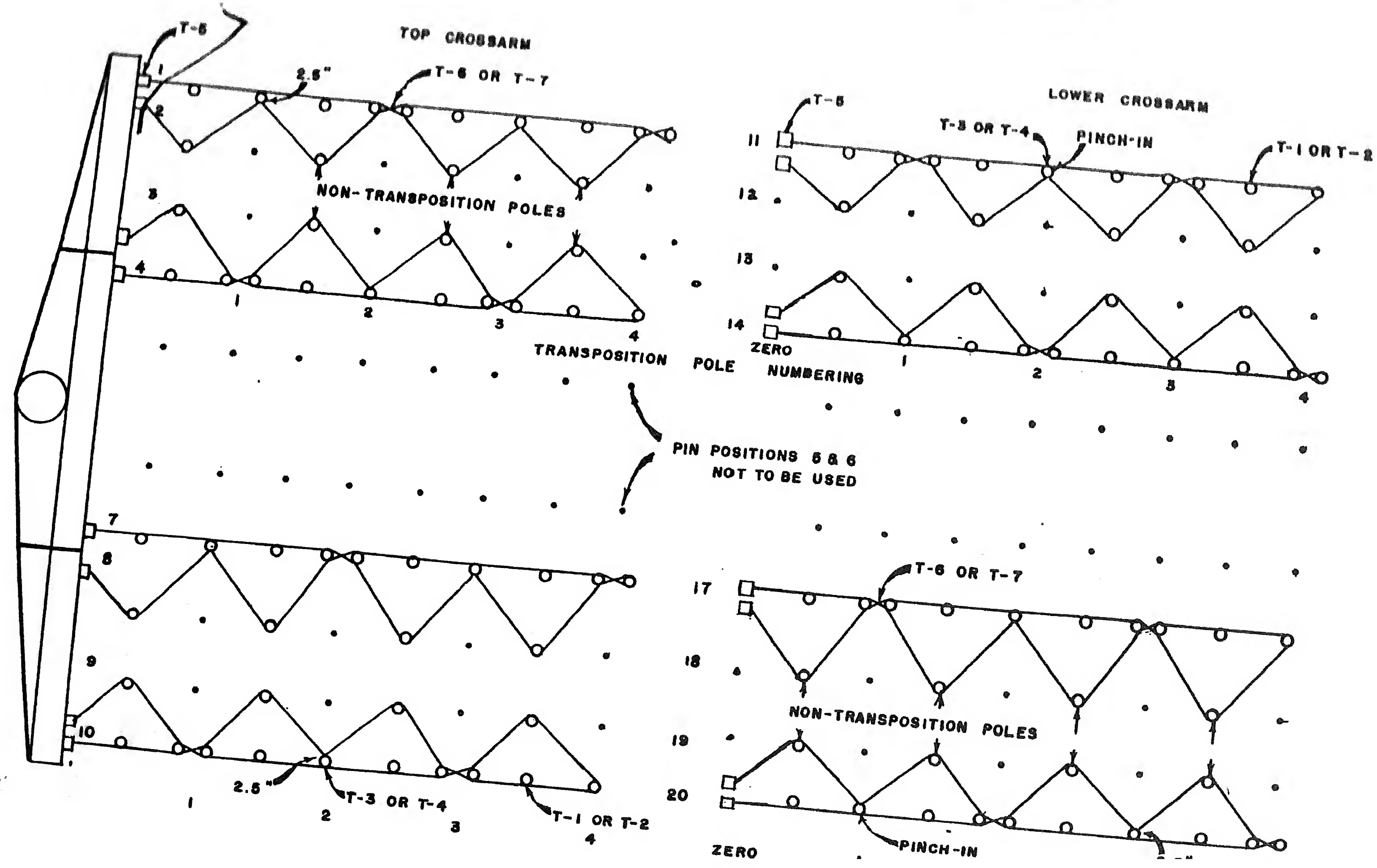
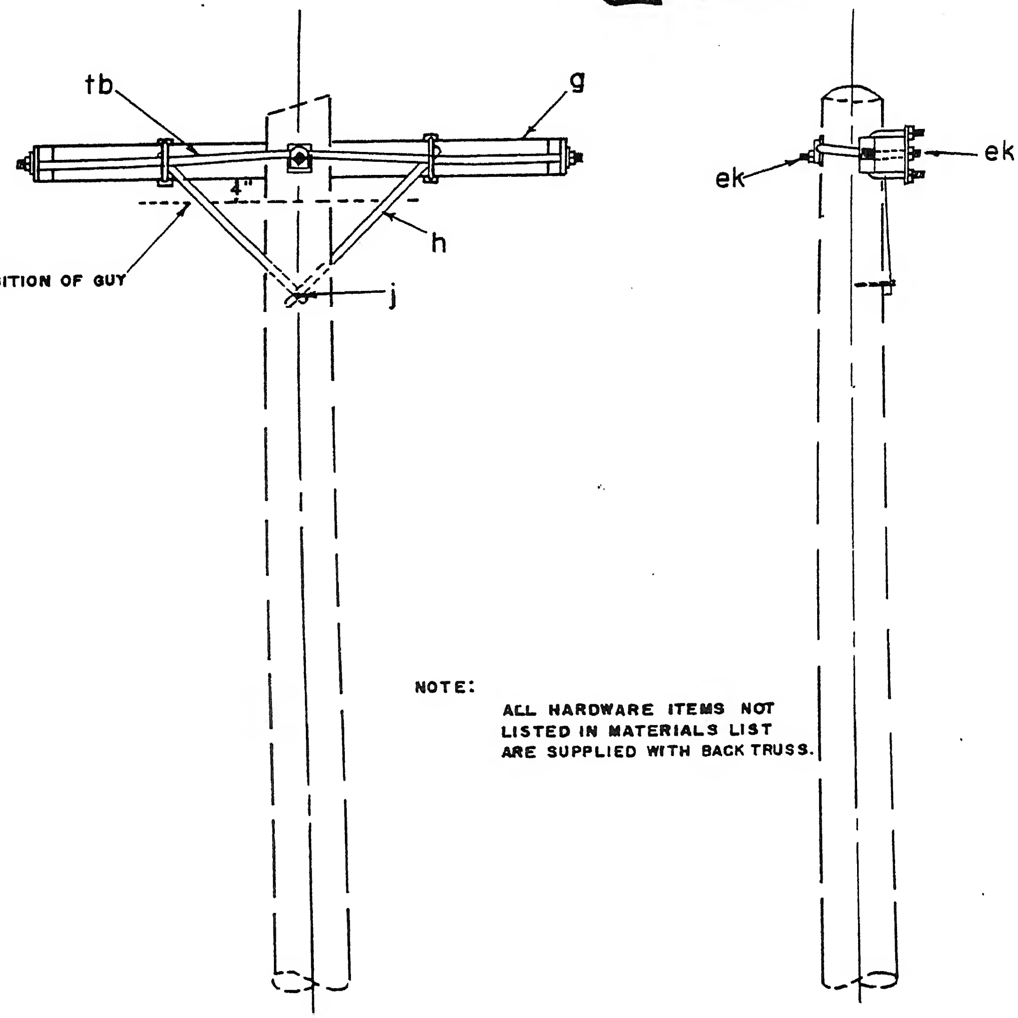


FIGURE 6

TREATMENT OF LINE WITH SHORT AVERAGE SPAN LENGTH
(EVERY OTHER POLE NORMALLY A TRANSPOSITION POLE)
FOR DETAIL OF DEAD-ENDING REFER TO UNIT PB5-14 (FIGURE 7 AND 8)





NOTE:
ALL HARDWARE ITEMS NOT LISTED IN MATERIALS LIST ARE SUPPLIED WITH BACK TRUSS.

ITEM	MATERIAL	ASSEMBLY UNITS			
		PB5-11	PB5-12	PB5-13	PB5-14
		NO. REQ'D.	NO. REQ'D.	NO. REQ'D.	NO. REQ'D.
g	CROSSARM, 3 1/4" X 4 1/4" X 10'-0" (TYPE DETA)	1	—	—	—
g	CROSSARM, 3 1/4" X 4 1/4" X 10'-0" (TYPE DETB)	—	1	—	—
g	CROSSARM, 3 1/4" X 4 1/4" X 10'-0" (TYPE DETC)	—	—	1	—
g	CROSSARM, 3 1/4" X 4 1/4" X 10'-0" (TYPE DETD)	—	—	—	1
tb	TRUSS, BACK, CROSSARM, 3/4" X 10'-0"	1	1	1	1
h	BRACE, FLAT, 1 7/32" X 7/32" X 30"	2	2	2	2
ek	LOCKNUT (FOR 5/8" BOLT)	2	2	2	2
j	SCREW, LAG, 1/2" X 4"	1	1	1	1

RURAL TELEPHONE CONSTRUCTION PRACTICES
DEADENDS, SINGLE CROSSARM (TYPES DETA, DETB, DETC, DETD)

SCALE: NTS | FIGURE 7 | DATE: JUNE 12, 1957

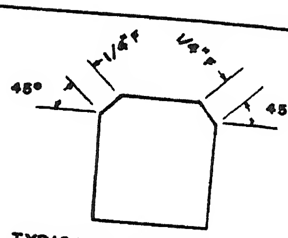
PB5-11, PB5-12, PB5-13, PB5-14

TOLERANCES

SIZES OF HOLES:

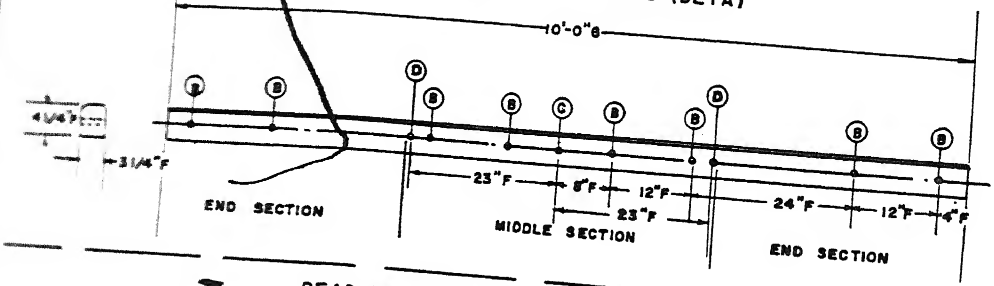
	NOMINAL	GO	NO GO
CLEVIS HOLE = (B)	7/16"	3/8"	1/2"
CENTER LINE = (C)	11/16"	5/8"	3/4"
BRACE HOLE = (D)	7/16	3/8	1/2

OTHER: F = 1/8" ±
G = 1/2" ±

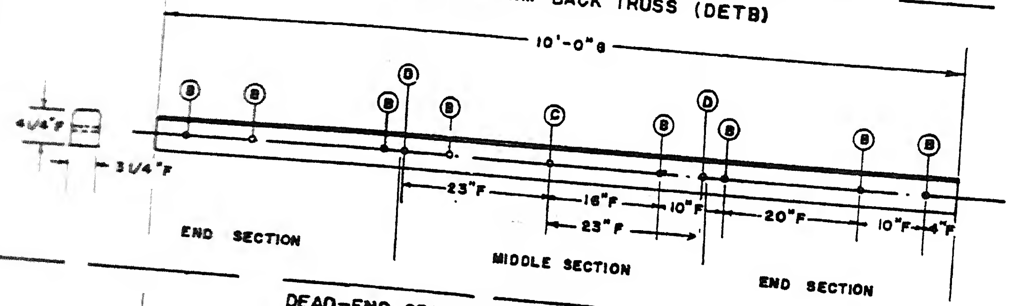


TYPICAL ENLARGED SECTION OF CROSSARM

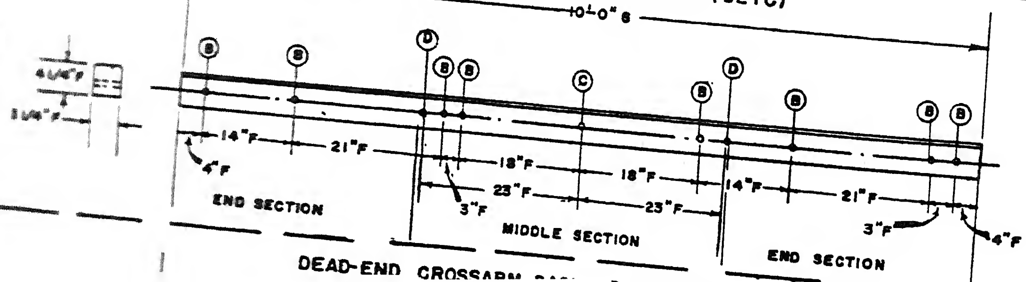
DEAD-END CROSSARM BACK TRUSS (DETA)



DEAD-END CROSSARM BACK TRUSS (DETB)



DEAD-END CROSSARM BACK TRUSS (DETC)



DEAD-END CROSSARM BACK TRUSS (DETD)

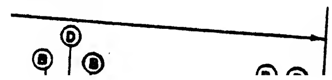
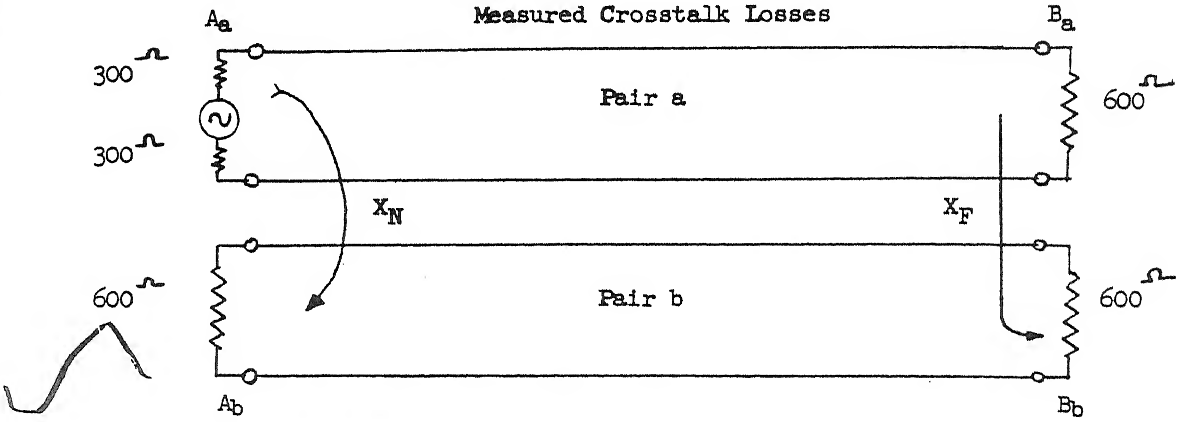


FIGURE 9

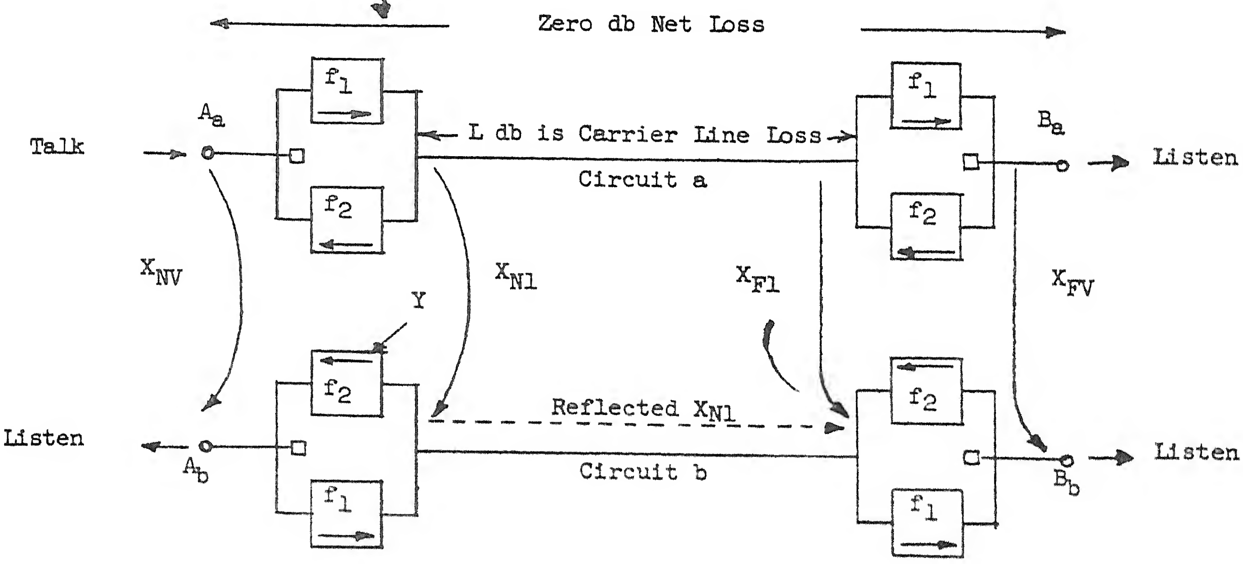
Crosstalk Losses

Measured Crosstalk Losses



Two Pairs with Similar Amplitude Modulated Carrier Systems

No Repeaters or Compandors



X_{N1} = Near-end Carrier Frequency Crosstalk Loss (Input to Output)
X_{F1} = Far-end Carrier Frequency Crosstalk Loss (Output to Output)
X_{NV} = Near-end Voice Frequency Crosstalk Loss (A_a to A_b)
X_{FV} = Far-end Voice Frequency Crosstalk Loss (B_a to B_b or A_a to B_b)

$$X_{FV} = X_{F1} \gtrsim 50 \text{ db}$$

$X_{NV} = X_{N1} - L + L_{f_1 f_2} \gtrsim 50$ db; $L_{f_1 f_2}$ is loss in filter at Y at frequency f_1.